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Technical Document 3288
December 2014

# DITEC User Priority Designation (UPD) Algorithm:

# An approach to prioritizing technology evaluations

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## ADMINISTRATIVE INFORMATION

This report was prepared for the Naval Innovative Science and Engineering (NISE) Program, by the Information Assurance Division, Cybersecurity Science and Technology Branch (Code 58230), SPAWAR Systems Center Pacific (SSC Pacific).

Released by
Jorge Alvarez, Head
Cybersecurity Science and
Technology Branch

Released under authority of
Elissa Huffstetler, Head
Information Assurance
Division

EG

# EXECUTIVE SUMMARY

DoD-Centric and Independent Technology Evaluation Capability (DITEC) users may decide that certain capability examinations are less meaningful for them than others. This paper introduces a system of prioritizing capability tests with DITEC and an algorithm that generates a weighted average based off of that prioritization

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# 1. INTRODUCTION

The DoD-Centric and Independent Technology Evaluation Capability (DITEC) allows users to perform a number of security evaluations of their computer networks. These evaluations take place at three levels (from highest to lowest): capability, sub-capability, and sub-capability element. It is entirely conceivable that a given user may place less emphasis (or perhaps none at all) on certain test capabilities, and a simple arithmetic mean of general test results may not provide meaningful analysis.

A solution to this problem is to institute a weighted average, but this begs the question of how to assign weights to the capabilities scored. Proposed is a 6-level ranking structure that, given 10 capability tests, would lead to 610 possible UPD combinations. A weighting algorithm is proposed which will assign weights to capability tests consistently, based on the users prioritizations.

## 2. DITEC USER PRIORITY DESIGNATION (UPD) AND UPD PROFILES

DITEC tests 10 capabilities, and so the user must prioritize all capabilities. The UPD scheme gives six priority levels: 0, 1, 2, 3, 4, 5. The UPD levels are as follows:

- UPD=0: No priority
- UPD=1: Minimal priority
- UPD=2: Low priority
- UPD=3: Moderate priority
- UPD=4: High priority
- UPD=5: Top priority

All capability tests must be assigned a UPD, and the user may assign multiple capabilities to the same UPD Level. Once a user has assigned a UPD to each capability, they have a UPD Profile $\mathrm{P} = \left( p_1 ... p_{10} \right)$. Once $\mathrm{P}$ has been established for a user, weights must be assigned to fit that specific set of priorities.

## 3. A FUNCTION ASSIGNING WEIGHTS BASED ON $\mathrm{P}$

Recall that a weighted average is a set of discrete numbers $\{x_1 ... x_n\}$ and weights $\{w_1 ... w_n\}$ such that

$$\langle x \rangle = \sum_{i=1}^{n} x_i w_i \text{ and} \sum_{i=1}^{n} w_i = 1 .$$

Weighted averages are often used in computing final grades in a class, and in determining atomic mass for the periodic table of elements [1]. In the present case, the analogy to calculating final grades for a class is more relevant. A professor has a semester class with two mid-term exams, a final exam, five quizzes, ten homework assignments, and attendance grades. It seems natural that the quizzes should have less impact on a student's overall grade than the exams, while homework may still have a different impact than the quizzes or the exams.

For every UPD Profile $\mathrm{P}$ there is a corresponding Weight Profile $\mathrm{W} = \{w_1 ... w_n\}$ and a function $f : \mathrm{P} \to \mathrm{W}$ mapping UPD level $i \mapsto w_i$. The weights $w_i \in [0,1] \cap \mathbb{Q}$ and $f$ must satisfy the following conditions:

- $f(0) = 0$: This allows the user to compute weighted averages that do not take unneeded capabilities into account.
- $f(0) = 0 < f(1) < f(2) < f(3) < f(4) < f(5) \leq 1$: Each UPD level is weighted higher than the preceding UPD level and lower than the subsequent UPD level. Capabilities at the same UPD level have the same weight.
- $1 = \sum_{w} w_i$ This is simply satisfying the requirement that the sum of all weights is 1.

# 4. A DESCRIPTION OF A WEIGHTING FUNCTION $f$

DITEC has ten capability tests at the highest level and the UPD framework allows each capability to have one of six priority designations, meaning that there are $6^{10}$ possible UPD Profiles. Certainly, there will be cases where certain UPD profiles may be equivalent for the purposes of the weighting function. There are also UPD profiles, which are unlikely to be chosen, e.g. a UPD profile with each $p_i = 0$. It would be unnecessarily costly to store a database of all possible UPD and weight profiles and so a weighting function $f$ is proposed that distributes weights in proportion to how each UPD level is distributed in $\mathrm{P}$. Moreover, $f$ should be similarly implementable at the sub-capability and sub-capability element levels, each of which will have different numbers of tests.

The weighting function $f$ can be visualized geometrically as equally partitioning a line segment, taking away a partition plus some extra, equally repartitioning the remaining line segment and repeating the process. The following sketch does not apply in the case that all capabilities are given the same UPD. In particular, suppose that for a particular $\mathrm{P}$ there are $n > 1$ UPD levels. Denote the initial remaining weight as $\mathrm{I}_0 = 1$ and partition $\mathrm{I}_0$ equally into $n$ pieces such that $j = \frac{1}{n}$. Take the first weight to be $j + j^2$.The remaining weight is $\mathrm{I}_1 = 1 - \left( j + j^2 \right)$. Now partition $\mathrm{I}_1$ equally into $n-1$ pieces where $(n-1) \cdot k = \mathrm{I}_1$ and $k = \frac{\mathrm{I}_1}{n-1}$. Take the second weight to be $k + k^2$. The remaining weight is $\mathrm{I}_2 = \mathrm{I}_1 - \left( k + k^2 \right)$. And so on.

## 5. AN EXAMPLE OF THE UPD WEIGHTING FUNCTION $f$

Suppose a UPD profile $\mathrm{P}$ in which ten capabilities are distributed among all six UPD levels, as shown in Table 1. Note that capabilities are numbered 1 through 10 rather than named in this example. The distribution of capabilities among the UPD levels is arbitrary and not terribly important except that we need to know how many UPD levels not equal to 0 are in a given $\mathrm{P}$ , in this case all five levels where UPD does not equal 0 are present.

Table 1. Example UPD Level Designation

| Capability | UPD |
|---|---|
| 1 | 1 |
| 2 | 0 |
| 3 | 2 |
| 4 | 3 |
| 5 | 1 |
| 6 | 5 |
| 7 | 3 |
| 8 | 4 |
| 9 | 5 |
| 10 | 5 |

We denote the weight at each step as $w_i$. Therefore we take $n = 5$, $\mathrm{I}_0 = 1$, and $j = \frac{1}{5}$. The first weight is:

$$w_1 = j + j^2 = \frac{1}{5} + \left(\frac{1}{5}\right)^2 = \frac{6}{24} = 0.24$$

The remaining weight after calculation of $w_1$ is $\mathrm{I}_1 = \mathrm{I}_0 - w_1 = \frac{19}{25}$. Now take $4k = \frac{19}{25}$, then $k = \frac{19}{100}$ and the second weight is:

$$w_2 = k + k^2 = \frac{19}{100} + \left(\frac{19}{100}\right)^2 = \frac{2261}{10000} = 0.2261$$

After two iterations the remaining weight, $w_3$, is $\mathrm{I}_2 = \mathrm{I}_1 - w_2 = \dfrac{5339}{10000}$. Now take $3l = \dfrac{5339}{10000}$, then $l = \dfrac{5339}{30000}$ and the third weight is:

$$w_3 = l + l^2 = \frac{5339}{10000} + \left(\frac{5339}{10000}\right)^2 = \frac{188674921}{900000000} = 0.20963880\overline{1}$$

After three iterations the remaining weight, $w_4$, is $\mathrm{I}_3 = \mathrm{I}_2 - w_3 = \dfrac{291835079}{900000000}$. This means we have assigned values for three weights, so two of them remain. Now take $2m = \dfrac{188674921}{900000000}$, then $m = \dfrac{188674921}{1800000000}$ and the fourth weight is:

$$w_4 = m + m^2 = \frac{188674921}{1800000000} + \left(\frac{188674921}{1800000000}\right)^2 = \frac{610470855534936241}{3240000000000000000} = 0.188416930\overline{7}$$

After four iterations the remaining, and final, weight, $w_5$, which makes calculation much simpler. The fifth weight is:

$$w_5 = \mathrm{I}_4 = \mathrm{I}_3 - w_4 = \frac{440135428865063759}{3240000000000000000} = 0.135844268168229555\overline{2469135802}.$$

Table 2 summarizes the UPD levels designations for each of the capabilities in the example, as well as the calculated weight for each of them.

Table 2. Summary of Example UPD Levels and Weights

| UPD | Capability | Weight # | Weight Value |
|---|---|---|---|
| 0 | 2 | 0 | 0 |
| 1 | 1, 5 | $w_5$ | 0.135844 |
| 2 | 3 | $w_4$ | 0.18841 |
| 3 | 4, 7 | $w_3$ | 0.20963 |
| 4 | 8 | $w_2$ | 0.2261 |
| 5 | 6, 9, 10 | $w_1$ | 0.24 |

After two or three iterations of our weighting function $f$, the fractions do get to a size that would be difficult for a person to calculate, but this is a trivial matter for a computer. It is clear that $f$ satisfies the conditions set earlier. This weighting function $f$ works irrespective of how many capabilities are at the level being tested or how many capabilities are at a given UPD level. Thus it should be implementable at any level for analysis.

## 6. AN ALGORITHM FOR $f$

1. Begin $f$ .
2. If there is only one UPD level, all tests are equally weighted.
3. Else, if there are multiple UPD levels:
4. Define $\mathrm{I}_0 = 1$
5. Define $n :=$ the number of UPD levels
6. For $i \geq 1$, define $j_i = \dfrac{\mathrm{I}_{i-1}}{n - i + 1}$
7. For $i \geq 1$, define $w_i = j_i + j_i^2$
8. For $i > 1$, define $\mathrm{I}_i = \mathrm{I}_{i-1} - w_i$
9. While $n - i + 1 \geq 2$, compute $j_i, w_i, \mathrm{I}_i$
10. If $n - i + 1 = 1$, $w_i = \mathrm{I}_{i-2} - w_{i-1}$
11. End $f$ when $n - i + 1 = 0$

# 7. REFERENCES

[1] Terr, David. “Weighted Mean." From MathWorld-A Wolfram Web Resource, created by Eric W. Weisstein. http://mathworld.wolfram.com/WeightedMean.html

| **REPORT DOCUMENTATION PAGE** | *Form Approved*<br>*OMB No. 0704-01-0188* |
|---|---|



| **1. REPORT DATE** *(DD-MM-YYYY)* | **2. REPORT TYPE** | **3. DATES COVERED** *(From - To)* |
|---|---|---|
| 12-2014 | Final | |

| | |
|---|---|
| **4. TITLE AND SUBTITLE**<br>DITEC User Priority Designation (UPD) Algorithm:<br>An approach to prioritizing technology evaluations | **5a. CONTRACT NUMBER**<br><br>**5b. GRANT NUMBER**<br><br>**5c. PROGRAM ELEMENT NUMBER** |
| **6. AUTHORS**<br>Roger Hallman<br>Jose Romero-Mariona<br>Megan Kline<br>John San Miguel | **5d. PROJECT NUMBER**<br><br>**5e. TASK NUMBER**<br><br>**5f. WORK UNIT NUMBER** |
| **7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**<br>Space and Naval Warfare Systems Center Pacific (SSC Pacific)<br>San Diego, CA 92152–5001 | **8. PERFORMING ORGANIZATION REPORT NUMBER**<br>TD 3288 |
| **9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**<br>Naval Innovative Science and Engineering Program | **10. SPONSOR/MONITOR'S ACRONYM(S)**<br>NISE<br><br>**11. SPONSOR/MONITOR'S REPORT NUMBER(S)** |

**12. DISTRIBUTION/AVAILABILITY STATEMENT**
Distribution statement A – Approved for public release.

**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**
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**15. SUBJECT TERMS**

| **16. SECURITY CLASSIFICATION OF:** | | | **17. LIMITATION OF ABSTRACT** | **18. NUMBER OF PAGES** | **19a. NAME OF RESPONSIBLE PERSON** |
|---|---|---|---|---|---|
| **a. REPORT** | **b. ABSTRACT** | **c. THIS PAGE** | | | Jose Romero-Mariona |
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